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[54] **AUTOMATIC SOLUTION MIXING APPARATUS**

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[52] **U.S. Cl.** **364/502**; 73/864.16; 417/403

[58] **Field of Search** 364/500, 502, 479, 510, 364/140; 73/863.31, 863.33, 863.54, 863.83, 864.13, 864.16, 864.17, 864.18; 222/56; 417/17, 403

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[57] **ABSTRACT**

An automatic solution mixing apparatus is provided with a plurality of solution distributors located on opposite sides of a common base plate supported on a supporting block. The support block is movable in opposite directions. Pistons of the solution distributors are connected to the common base plate so that dual solution mixing operations can be performed by the solution distributors with a high degree of accuracy. Moreover, a stepping motor is utilized as a driving motor, and the operation of the stepping motor can be controlled by controlling the number of pulses supplied to the driving motor without using a rotaty encoder.

3 Claims, 5 Drawing Sheets

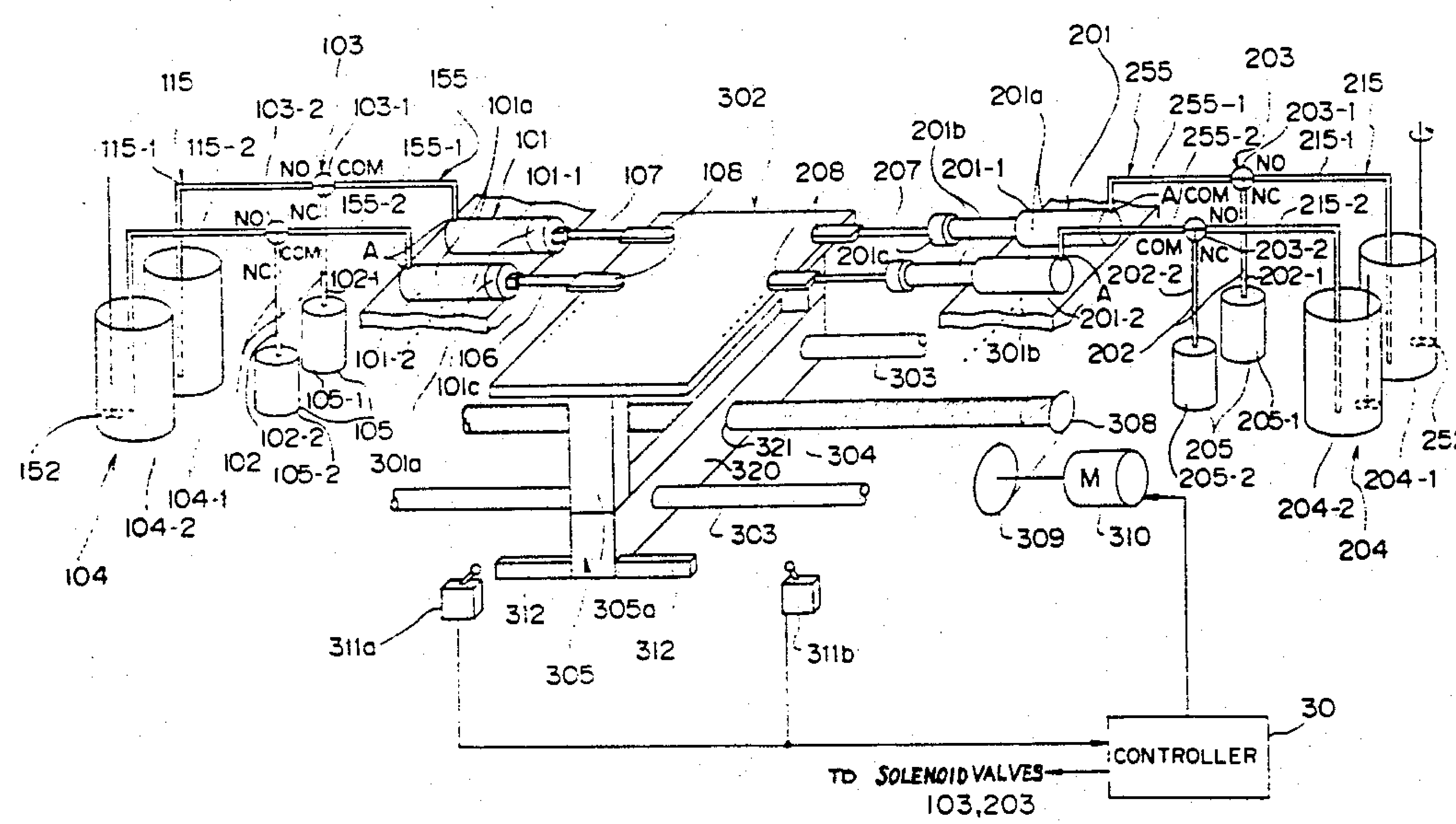


Fig. 1 (PRIOR ART)

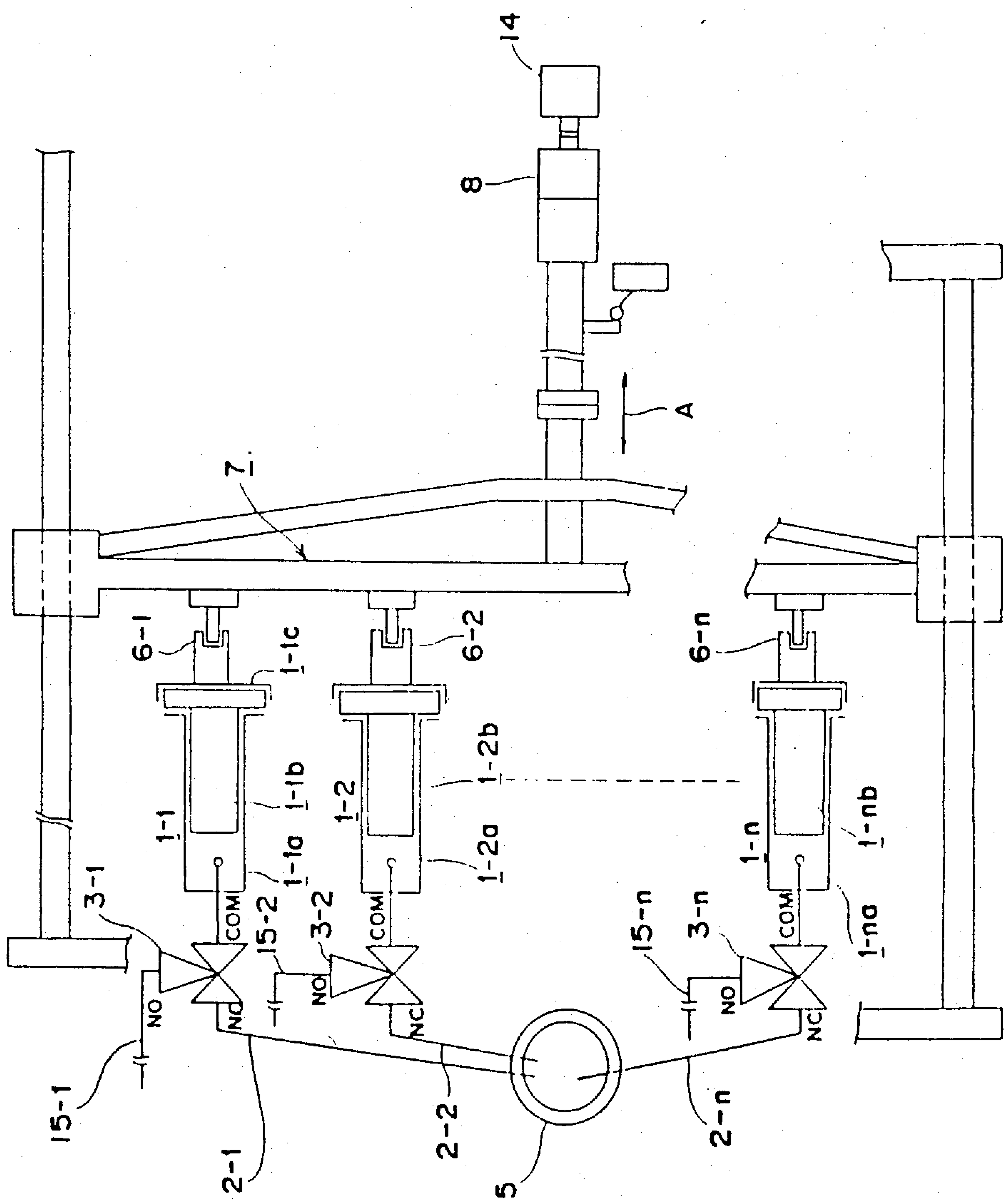


Fig. 2

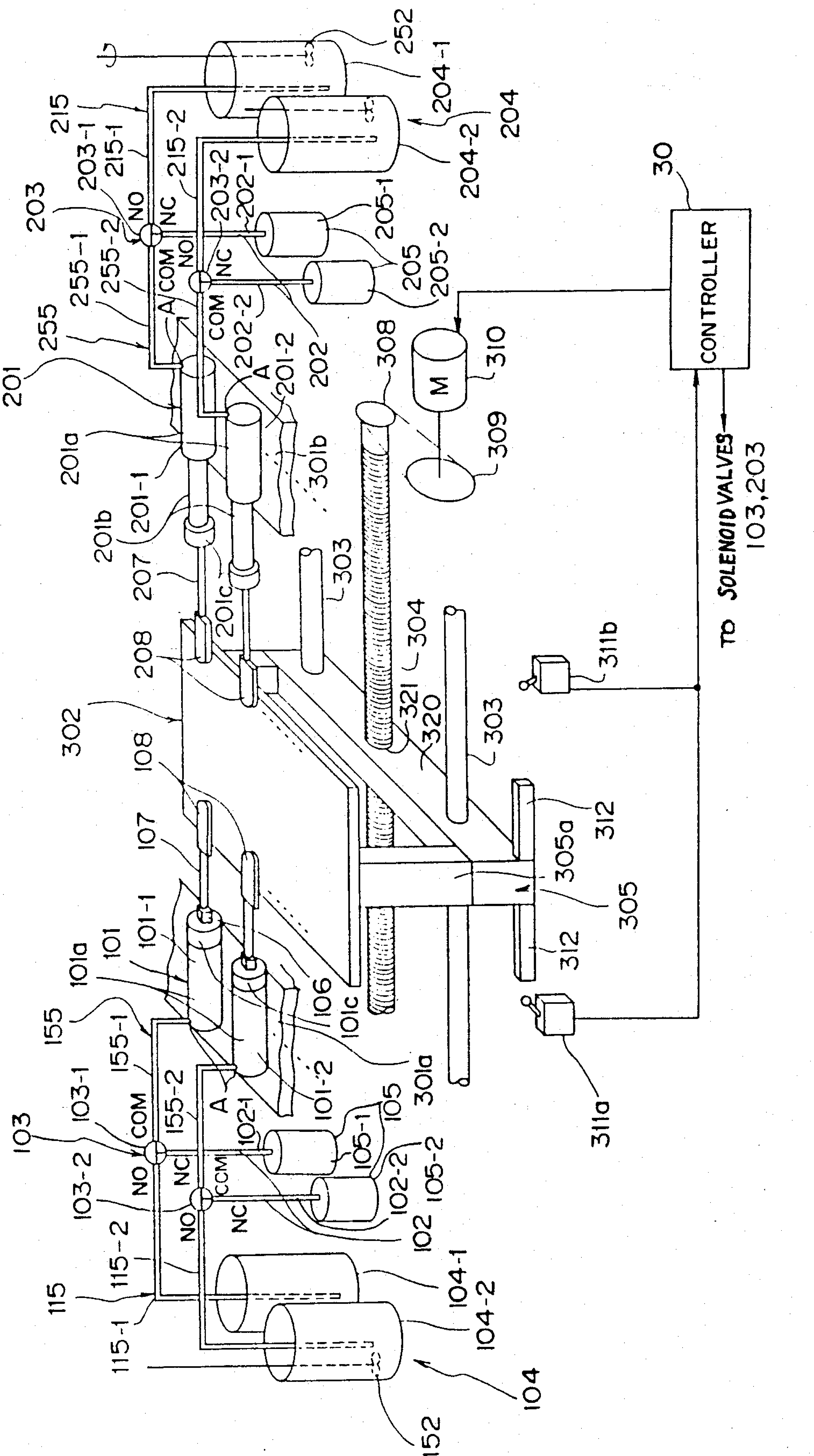
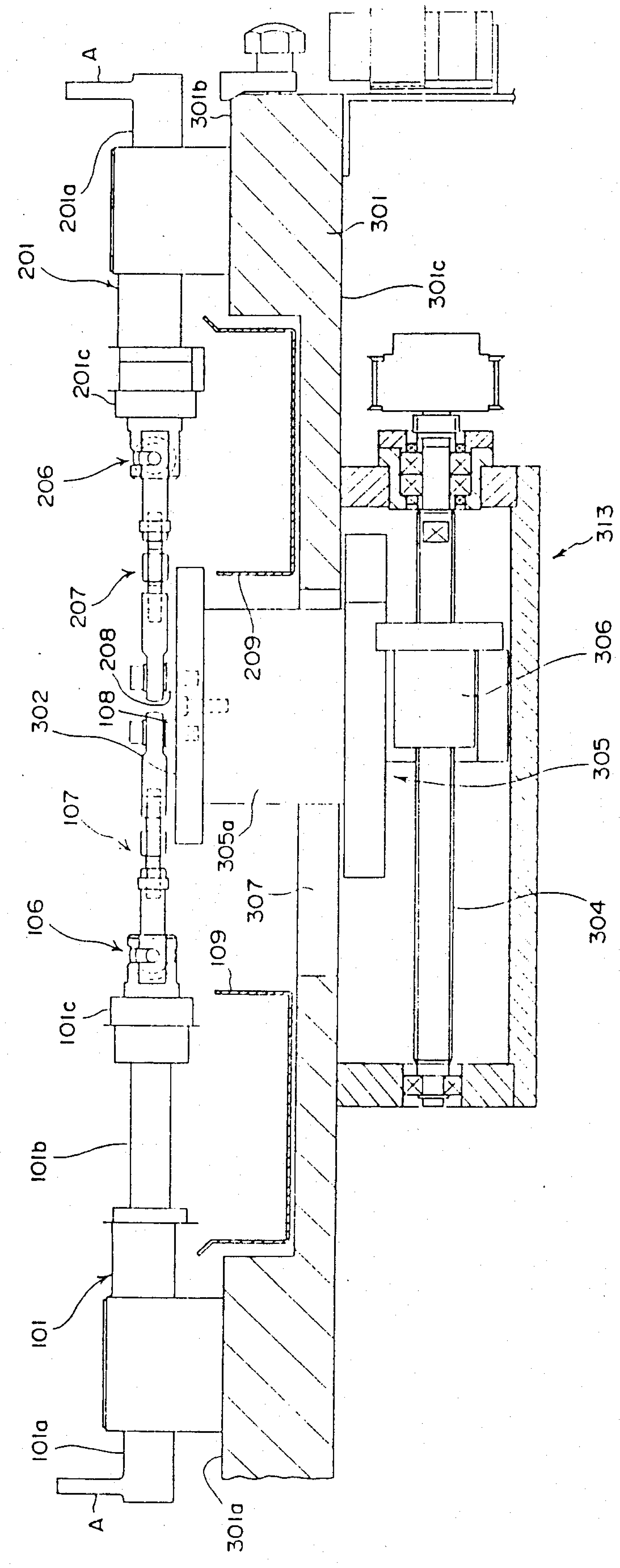

CONTROLLER
30
M
310
TO SOLENOID VALVES
103,203
COM
NO
NC
A
201
202
203
204
205
255
215
252
101
102
103
104
105
106
107
108
115
152
155
208
207
302
303
304
305
305a
308
309
311a
311b
312
320
321

Fig. 3


A
301b
201a
201
301
301c
201c
206
313
207
208
209
306
302
108
305
107
305a
307
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106
109
101c
101b
101
101a
A
301a

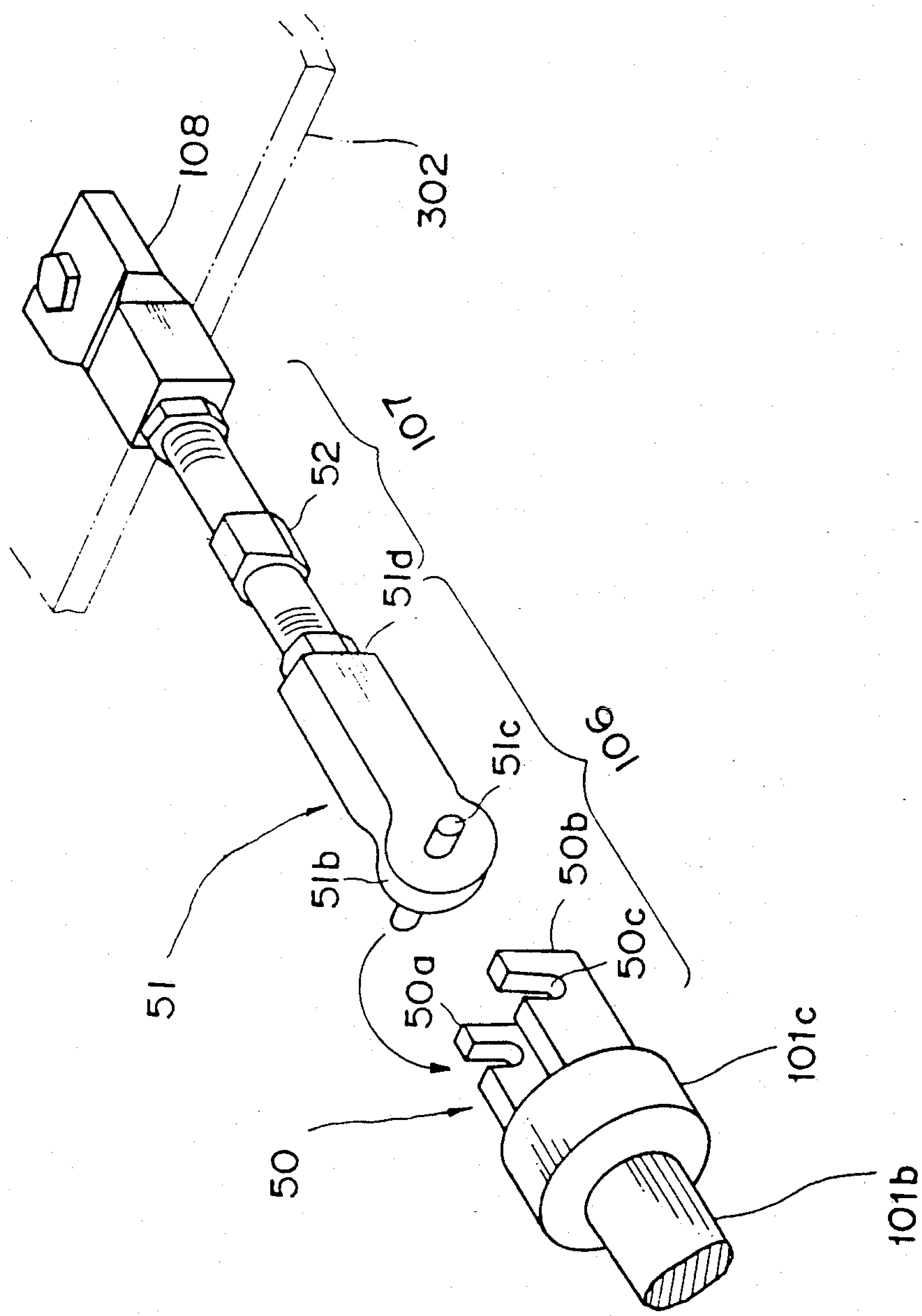
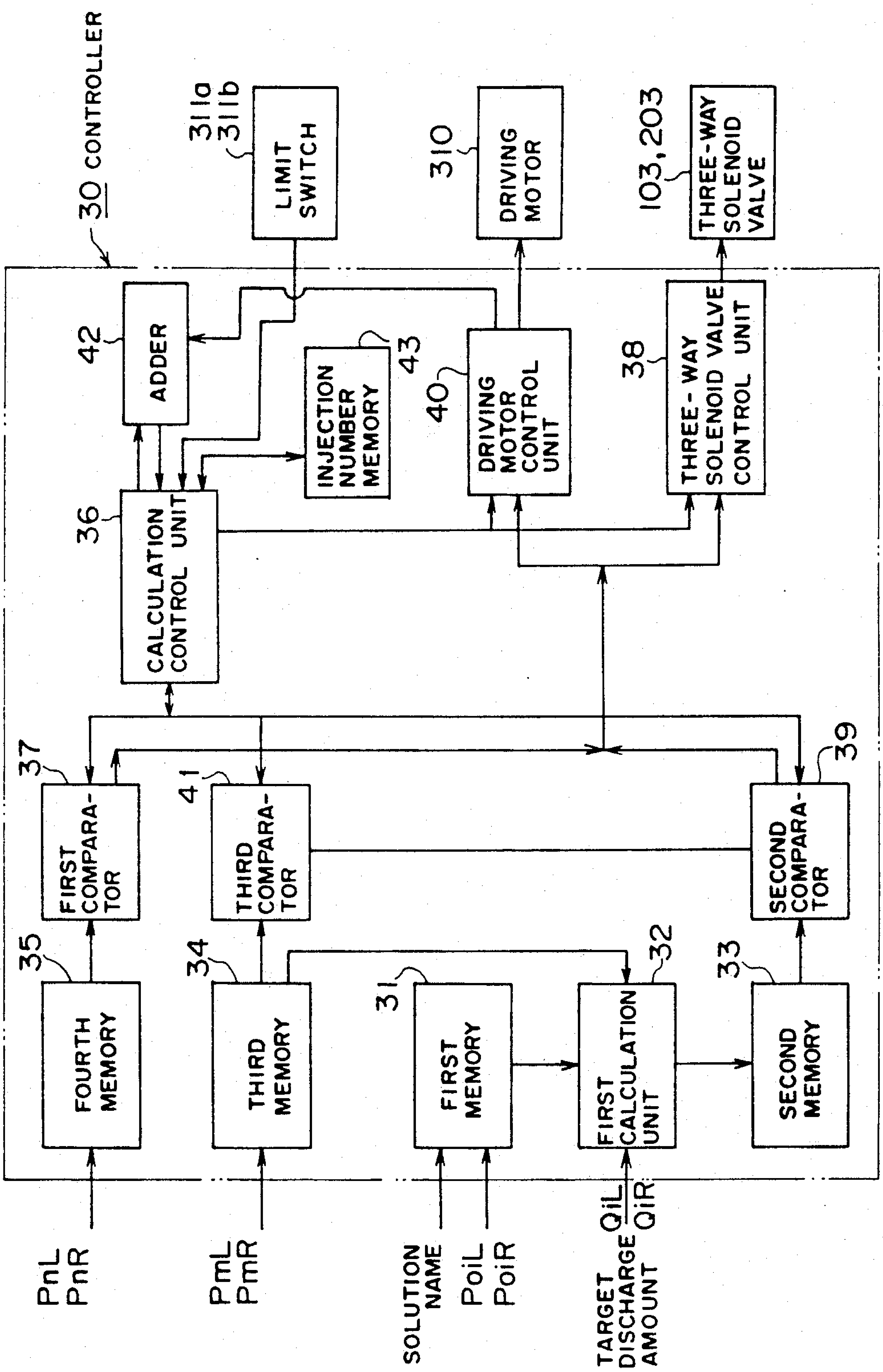


Fig. 4

Fig. 5


30 CONTROLLER
311a
311b
LIMIT SWITCH
310
DRIVING MOTOR
103,203
THREE-WAY SOLENOID VALVE
42
ADDER
43
INJECTION NUMBER MEMORY
40
DRIVING MOTOR CONTROL UNIT
38
THREE-WAY SOLENOID VALVE CONTROL UNIT
36
CALCULATION CONTROL UNIT
37
FIRST COMPARA-TOR
41
THIRD COMPARA-TOR
39
SECOND COMPARA-TOR
35
FOURTH MEMORY
34
THIRD MEMORY
31
FIRST MEMORY
32
FIRST CALCULATION UNIT
33
SECOND MEMORY
PnL
PnR
PmL
PmR
SOLUTION NAME
PoiL
PoiR
TARGET DISCHARGE AMOUNT
QiL
QiR

AUTOMATIC SOLUTION MIXING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an automatic solution mixing apparatus for use with dying, developing, etching solutions and the like.

2. Description of the Prior Art

One of the present inventors has previously proposed an automatic solution mixing apparatus in Japanese Patent Laid Open Application No. 026980/1990. The automatic solution mixing apparatus disclosed in the above-mentioned patent application comprises, as shown in FIG. **1**, a plurality of solution distributors **1-1**, **1-2**, . . . , **1**-n (hereinafter represented by the solution distributors **1**) which suction and discharge solutions by the reciprocal movement of pistons **1-1***b*, **1-2***b*, . . . , **1**-*nb* (hereinafter represented by **1**-*b*) inserted in cylinders **1-1***a*, **1-2***a*, . . . , **1**-*na* (hereinafter represented by **1**-*a*). The solution distributors are arranged in a row and are respectively connected to three-way solenoid valves **3-1**, **3-2**, . . . , **3**-*n* (hereinafter represented by three-way solenoid valves **3**) through common ports (COM) thereof. The three-way solenoid valves **3** are connected to solution tanks (not shown) through solution intake pipes **15-1**, **15-2**, . . . , **15**-*n*, respectively, for receiving solutions from the solution tanks. Also, the three-way solenoid valves **3** are connected to a solution receiver **5** through injection pipes **2-1**, **2-2**, . . . , **2**-n, respectively, for discharging solutions from the solution distributors **1** to the solution receiver **5**.

The pistons **1**-*b* of the solution distributors **1** are respectively coupled through couplings **6-1**, **6-2**, . . . , **6**-n to an actuating arm **7** for driving all of the pistons with the same stroke in the same direction. The movement of the arm **7** in the direction as indicated with an arrow A, i.e., back and forth movement, is performed by the normal and reverse rotation of a driving motor **8**, and the amount of the back and forth movement is controlled by the number of pulses of the pulse signal fed from a rotary encoder **14** which detects the number of revolutions of the motor **8**.

Accordingly, since the back and forth movement of the actuating arm **7** corresponds to that of the pistons **1**-*b*, the amount of movement of the pistons **1**-*b* can be controlled by controlling the amount of the back and forth movement of the arm **7**, i.e., the number of pulses fed from the rotary encoder **14**. Moreover, since the amount of movement of the pistons **1**-*b* corresponds to the amount of the solution discharged from the distributors **1**, by selecting the above-mentioned number of pulses per unit discharge amount in advance, the amount of solution discharged from the cylinders **1**-*a* can be controlled.

The operation of such an automatic solution mixing apparatus will now be hereinafter described. In the first step, with the three-way solenoid valves **3** having their valve passages opened to the solution tanks, the driving motor **8** is so operated as to move the pistons **1**-*b* in a direction of extending the pistons from the cylinders **1**-*a*, i.e., to move the actuating arm **7** backward. Accordingly, the solution is suctioned from the solution tank into each distributor **1** so as to fill the same.

The number of pulses corresponding to the amount of solution to be discharged from each distributor **1** is then set in a control section (not shown), so that the control section will control the operation of the driving motor **8** based upon the number of the above-mentioned set pulses and the number of the pulses supplied from the encoder **14**.

Subsequently, the driving motor **8** is rotated to move the actuating arm **7** forward, i.e., to retract the pistons **1**-*b* into the cylinders **1**-*a* to eject air bubbles therefrom, and thereafter perform an operation for mixing a plurality of solutions. In the solution mixing operation, the solutions are discharged in a manner of increasing the amount of solutions discharged from the distributors **1**, i.e., increasing the number of the pulses set in the control section, and the control section operates the driving motor **8** to move the actuating arm **7** forward until the discharged amount of the solution reaches specified amount of discharge for each distributor **1** set in the control section. For the distributor **1** in which the discharge of a desired amount of solution has been completed, the three-way solenoid valve **3** located on the discharge side of the cylinder is opened to the solution tank and the solution remaining in the cylinder **1**-*a* (hereinafter called the residual solution) is ejected into the solution tank. This operation is repeated for every solution distributor **1** to mix the solutions.

Although the automatic solution mixing apparatus described above is capable of mixing many kinds of solutions accurately, the solution distributors **1** must be arranged in a row to accommodate a driving gear including the actuating arm **7**, driving motor **8** and so on behind the distributors **1**, and the number of the solution distributors **1** connected to the driving gear is limited because of the limited length of the actuating arm **7**. Therefore, when a large number of solution distributors **1** are required, a plurality of sets of the driving gears and the solution distributors **1** have to be provided, which requires the automatic solution mixing apparatus to be made large.

SUMMARY OF THE INVENTION

It is an object of the present invention to eliminate such a problem as mentioned above and to provide an automatic solution mixing apparatus which may be provided with a larger number of solution distributors without making the size thereof large and which is capable of mixing the solutions accurately.

According to a first aspect of the present invention, the automatic solution mixing apparatus comprises: one or more pairs of solution distributors for suctioning solutions into their cylinders and discharging the solutions therefrom by the movement of pistons in the cylinders, the distributors of each pair being substantially disposed face-to-face each with their pistons extending in opposite directions; a piston connecting mechanism for connecting both pistons of each pair of distributors in such a way that the movement of the pistons in the cylinders located on one side of the apparatus is opposite to that of the pistons in the cylinders located on the other side; and piston driving means for driving the pistons to suction the solutions into the solution distributors and discharge a predetermined amount of solutions therefrom.

According to another aspect of the present invention, the automatic solution mixing apparatus comprises: one or more pairs of solution distributors for suctioning solutions into their cylinders and discharging the solutions therefrom by the movement of pistons in the cylinders, the distributors of each pair being substantially disposed face-to-face with their pistons extending in opposite directions; a plurality of pairs of solution tanks corresponding to the respective solution distributors for containing ingredient solutions to be mixed; one or more pairs of solution receivers for containing mixed solutions; three-way solenoid valves for selectively placing the solution distributors in communication with the solution tanks or with the solution receivers depending on a control signal issued thereto; piston connecting means for connecting the pistons in each pair of distributors in such a way that the movement of the pistons in the cylinders located on one side of the apparatus is equal and opposite to that of the pistons in the cylinders located on the other side; piston driving means for driving the piston connecting means to suction the solutions into the solution distributors and to discharge a predetermined amount of solutions therefrom; solenoid valve control means for selectively feeding signals to the three-way solenoid valves to open the valve passages of the three-way solenoid valves to a solution tank and to switch over the valve passages so as to be open to the solution receivers; calculation means for calculating the quantity of solutions to be discharged into the receivers from each of the distributors; driving motor control means for selectively feeding signals to actuate the piston driving means; and control means for controlling the operation of the solenoid valve control means and the driving motor control means based on calculations made by said calculation means.

As mentioned above, the piston connecting means connects the pistons of the solution distributors in such a manner that the movement of the pistons of each distributor on one side of the apparatus is equal and opposite to that of the pistons of each distributor on the other side of the apparatus. The piston driving means reciprocates the piston connecting means over a distance by which the pistons can be moved within the stroke of the distributors. In this way, when those pistons of a group of solution distributors on one side of the apparatus, which face a group of solution distributors on the other side, are retracted into their cylinders, for example, those pistons of the group of the solution distributors on the other side will be extended from their cylinders. And when the situation is reversed, the respective groups of the solution distributors will then be operated in reverse. Thus, the automatic solution mixing apparatus according to the present invention will perform the solution mixing operation by operating at least two groups of solution distributors in one operation in which the distributors of one group suction solutions while the distributors of the other group discharge solutions. As a result, a solution mixing operation is effected accurately without the need for a large automatic solution mixing apparatus.

The present invention together with further objects and advantages thereof may best be understood by referring to the following detailed description, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a conventional automatic solution mixing apparatus;

FIG. 2 is a perspective view of an embodiment of an automatic solution mixing apparatus according to the present invention;

FIG. 3 is a partial cross-sectional view of a main portion of the apparatus shown in FIG. 2;

FIG. 4 is a perspective view of a coupling portion of the apparatus shown in FIG. 2; and

FIG. 5 is a block diagram of an embodiment of a control unit for the automatic solution mixing apparatus according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIGS. 2 and 3 depicting one embodiment of an automatic solution mixing apparatus according to the present invention, a plurality of groups of solution distributors **101-1**, **101-2**, . . ., **101-*n*** and **201-*n***, **201-2**, . . ., **201-*n*** suction and discharge solutions by the backward and forward movement of their respective pistons. The cylinders in each such group are disposed in parallel and are spaced apart appropriately in the longitudinal direction of a pair of flat bases **301*a*** and **301*b***, respectively, which extend parallel to each other so that the groups of pistons **107** and **207** face each other in coaxial alignment, the cylinders being mounted to the bases in a horizontal state. It is to be noted that the respective solution distributors fixed on the bases **301*a*** and **301*b*** may be referred to merely as the solution distributors **101** and **201**, respectively.

The solution distributors **101** and **201** mentioned above comprise the cylinders **101*a*** and **201*a***, and pistons **101*b*** and **201*b*** reciprocating in these cylinders. The pistons **101*b*** and **201*b*** of the solution distributors **101** and **201** are respectively connected with a common movable base plate **302** through connecting rods **107** and **207**. With this construction, the solution distributors **101** discharge solutions and the solution distributors **201** suction the same when the common base plate **302** is moved to the left in the figures, whereas the solution distributors **201** discharge solutions and the solution distributors **101** suction the same when the common base plate **302** is moved to the right in the figures. Each of the solution distributors **101** and **201** has a solution intake/discharge port A directed vertically from the closed end of the cylinders **101*a*** and **201*a***, respectively. Three-way solenoid valves **103-1**, **103-2**, . . ., **103-*n*** (represented by the valves **103** hereinafter) are respectively connected to the solution intake/discharge ports A of the distributors **101** through intake/discharge pipes **155-1**, **155-2**, . . ., **155-*n*** (represented by pipes **155** hereinafter). Similarly, three-way solenoid valves **203-1**, **203-2**, . . ., **203-*n*** (represented by valves **203** hereinafter) are respectively connected to the solution intake/discharge ports A of the distributors **201** through intake/discharge pipes **255-1**, **255-2**, . . ., **255-*n*** (represented by pipes **255** hereinafter). Each of the three-way solenoid valves **103** has a normally open port (NO), common port (COM) and normally closed port (NC), wherein the normally open ports NO are respectively connected to solution tanks **104-1**, **104-2**, . . ., **104-*n*** (represented by solution tanks **104** hereinafter) through solution pipes **115-1**, **115-2**, . . ., **115-*n*** (represented by solution pipes **115** hereinafter), and the common ports COM are respectively connected to the cylinders **101*a*** through intake/discharge pipes **155**, and the normally closed ports NC are respectively connected to solution receivers **105-1**, **105-2**, . . ., **105-*n*** (represented by receivers **105** hereinafter) through injection pipes **102-1**, **102-2**, . . ., **102-*n*** (represented by injection pipes **102** hereinafter). When the solenoid of each valve is energized (turned on), the passage (COM-NC) will open to place the injection pipes **102** associated with the respective receivers **105** in communication with the solution distributors **101**, whereas when the solenoid of the valve is de-energized (turned off), the passage

(COM-NO) will be open to place the pipes **115** associated with the tanks **104** in communication with the solution distributors **101**.

Similarly, each of the three-way solenoid valves **203** has the same construction as those of the three-way solenoid valves **103**.

In each of the tanks **104** (**204**), there is provided an agitator **152** (**252**) which agitates a condensed solution contained in the tank. The receivers **105** (**205**) are respectively mounted on a turntable or belt conveyer (not shown) so that they can be moved into alignment with the nozzles of the injection pipes **102** (**202**). For example, the first receiver **105** receives a desired amount of the first solution through the injection pipe **102-1** of the solution distributor **101-1**, and this receiver **105-1** is moved to the second position corresponding to the injection pipe **102-2** of the solution distributor **101-2** to receive a desired amount of the second solution therefrom. In this way, i.e., by moving the receivers to the injection pipes of desired solution distributors so as to receive their individual solutions, the solutions are mixed. Although, in this embodiment shown in FIG. **2**, the solution distributors **101** (**201**) are individually provided with solution receivers **105** (**205**) connected thereto for receiving solutions, a pair of solution receivers may be provided as shown in FIG. **1**; in other words, one solution receiver is provided in association with the solution distributors **101** for receiving the solutions injected through the respective injection pipes **102** and the other solution receiver is similarly provided in association with the solution distributors **201**.

Moreover, although respective ingredient solution tanks **104** (**204**) are provided for each of the solution distributors **101** (**201**), there may be provided a single ingredient solution tank for receiving solutions fed from a plurality of solution distributors **101** (**201**) through a plurality of solution pipes **115** (**215**).

As shown in FIGS. **3** and **4**, metal rings **101***c* (**201***c*) are mounted on the end portions of the piston **101***b* (**201***b*), and coupling mechanisms **106** (**206**) are provided for coupling the metal rings **101***c* (**201***c*) with the connecting rods **107** (**207**) which are fixed with the common base plate **302** by rod linkage metal fittings **108** (**208**). It is noted that, although FIG. **4** shows these parts only on the side of the solution distributors **101**, their arrangement is identical with that of those on the side of the solution distributors **201** and the explanation thereof is omitted for brevity.

Each coupling **106** includes a forked "U"-member **50** fixed on the end surface of the metal ring **101***c* and a joint member **51** connected to the connecting rod **107**. The forked member **50** comprises two arms **50***a* and **50***b* appropriately spaced apart from each other, each having an oval recess **50***c* having its longer axis running perpendicularly to the longitudinal direction of each of the arms **50***a* and **50***b* and open at one end thereof. The joint member **51** has a flat connecting plate **51***b* which is removably inserted in the space between the arm plates **50***a* and **50***b* and is attached thereto. The connecting plate **51***b* of the joint member **51** has a cylindrical stem rod **51***c* extending perpendicularly through the center of the connecting plate **51***b* and fixed thereto. The cylindrical stem rod **51***c* is slidingly movable in close contact with the surfaces defining recesses **50***c* in the arm plates **50***a* and **50***b*. That is to say, the forked member **50** and the joint member **51** are engaged with each other in such a way that the connecting plate **51***b* is inserted in the space between the arm plates **50***a* and **50***b* of the forked member **50** with the stem rod **51***c* received in the recesses **50***c*. The coupling mechanism **106** thus constructed is advantageous in that it allows flexibility of the angles that the solution distributors **101** make with respect to the connecting rod **107** fixed to the common base plate **302** through the rod linkage metal fitting **108**, thereby facilitating an adjustment of the solution distributors **101**. The connecting rod **107** comprises a round bar with threaded ends and a hexagon nut **52** fixed at the intermediate portion thereof and through which the round bar is passed. The connecting rod **107** has one threaded end portion engaged in a threaded hole open at an end surface **51***d* of the joint member **51** opposite to the connecting plate **51***b* and has the other threaded end portion engaged in a threaded hole formed at an end surface of the rod linkage metal fitting **108** fixed on the common base plate **302**.

In this way the piston **101***b* of each of the solution distributors **101** is connected to the common base plate **302** through a coupling mechanism **106** and connecting rod **107**. In addition, by turning the hexagon nut **52** fixed on the intermediate portion of the connecting rod **107**, the length of the portion of the connecting rod **107** inserted in the joint member **51** and the length of the portion thereof inserted in the rod linkage metal fitting **108** can be adjusted to perform a fine adjustment of the position of the piston **101***b* relative to the cylinder **101***a* of the solution distributor **101**.

As shown in FIGS. **2** and **3**, the common base plate **302** is supported by a supporting block **305** which is movable longitudinally in the figures. Through a base member **320** of the supporting block **305**, there are provided two guide bars **303** extending horizontally in parallel with an appropriate space therebetween, whereby the supporting block **305** is guided for right-to-left movement in the figures. In the middle portion of the base member **320** there is formed a threaded hole **321** through which a shifting screw **304** in the form of a ball screw is inserted, so that the supporting block **305**, i.e., the common base plate **302**, can be moved right and left in the figures by rotating the shifting screw **304**.

Two posts **305***a* extend vertically at the both ends of the top surface of the supporting block **305**, and the common base plate **302** is fixed on the posts **305***a* on the supporting block **305**. The rod linkage metal fittings **108** and **208** are fixed face-to-face on the common base plate **302**. A plurality of these metal fittings **108** (**208**) are arranged in positions corresponding to the solution distributors **101** (**201**) installed on the base **301***a* (**301***b*). In this embodiment, a solution distributor **101**, connecting rod **107**, pair of rod linkage metal fittings **108** and **208**, connecting rod **207** and solution distributor **201** are disposed in alignment. Since the common base plate **302** is flat, there is an advantage in that the rod linkage metal fittings **108** (**208**) can be easily fixed on the base plate **302** and detached therefrom so that parts including the solution distributors **101** (**201**) can be easily maintained.

When providing a rod linkage metal fitting which may be freely adjusted relative to the common base plate **302**, in addition to the rod linkage metal fitting **108** shown in FIG. **2**, the solution distributors can be arranged in four directions and the like. In this case, it is necessary to compensate for the amount of movement of the pistons corresponding to that of the supporting block **305**.

At one end of the shifting screw **304** there is provided a pulley **308** which is linked through a belt, for example, with a pulley **309** mounted on a driving shaft of a driving motor 310. The driving motor 310 is a reversible stepping motor whose operating time is controlled by the number of pulses supplied from a controller 30 to be described later.

Thus, by operating the driving motor 310, the shifting screw 304 is rotated so as to move the supporting block 305 and the common base plate 302 right and left along the longitudinal direction of the guide bars 303. The supporting block 305 is moved right and left in the figures in the space between the opposing pistons 101*b* and 201*b* of the solution distributors 101 and 201. In this embodiment, the supporting block 305 is moved longitudinally in an opening 307 formed in a substrate 301 to which the solution distributors 101 and 201 are fixed.

In order to detect the limit positions of the longitudinal movement of the supporting block 305, there are provided limit switches 311*a* and 311*b* on a fixed frame (not shown) for sending signals to stop the rotation of the driving motor 310. And there are provided detection bars 312 protruding from the supporting block 305 in the longitudinal direction for actuating the limit switches 311*a* and 311*b* when the supporting block 305 reaches the specified limit positions thereof. The limit positions are set within a range in which the pistons 101*b* and 201*b* can be moved in the cylinders 101*a* and 201*a* of the solution distributors 101 and 201 fixed on the both sides on the substrate 301.

In order to lubricate the pistons 101*b* (201*b*) within the cylinders 101*a* (201*a*), lubricant such as water or oil will be dropped from a location above the pistons 101*b* (201*b*) when the pistons are pulled out from the cylinders of the solution distributors 101 (201), and there are provided lubricant receivers 109 and 209 on the substrate 301 for receiving the lubricant. In this embodiment, a shifting unit 313 includes the guide bars 303, shifting screw 304 and supporting block 305 under a lower surface 301*c* of the substrate 301 so as to constitute a unit integrated with the substrate 301.

In this arrangement as mentioned above, when the supporting block 305 is shifted to the left in the figures for example, the pistons 101*b* will be retracted into the cylinders 101*a* (forward), and at the same time, the pistons 201*b* will be extended from the cylinders 201*a* (backward). When the supporting block 305 is shifted to the right, the pistons 101*b* and 201*b* are operated in reverse with respect to the operation mentioned above.

Accordingly, when the pistons 101*b* are extended from the cylinders 101*a* for example, since the three-way solenoid valves 103 are opened to the ingredient solution tanks 104, the solution distributors 101 will suction the solution contained in the solution tanks 104 into the cylinders 101*a* through the three-way solenoid valves 103 and intake/discharge ports A. At the same time, the solution distributors 201 will discharge the solution in the cylinders 201*a* through the intake/discharge ports A to the solution receivers 205 under the retraction of the pistons 201*b* into the cylinders 201*a*. Conversely, when the pistons 201*b* are extended from the cylinders 201*a*, since the three-way solenoid valves 203 are opened to the ingredient solution tanks 204, the solution distributors 201 will suction the solution contained in the solution tanks 204 into the cylinders 201*a* through the three-way solenoid valves 203 and intake/discharge ports A. At the same time, the solution distributors 101 will discharge the ingredient solution in the cylinders 101*a* through the intake/discharge ports A under the retraction of the pistons 101*b* into the cylinders 101*a*.

The operation of this embodiment of the automatic solution mixing apparatus having the structure mentioned above will now be described with reference to FIGS. 2, 3 and 5. To help one understand the operation, those solution distributors for distributing the solutions will be described in terms of the illustrated embodiment in which the distributors are arranged on the right and left sides of the common base plate 302 in FIG. 2. In the discussion, suffixes L and R depict items relating to the solution distributors 101 and 201 on the left and right, respectively.

For arriving at the number of pulses of the signal to be fed to the driving motor 310, the relation between the number of revolutions of the driving motor 310 depending on the number of the pulses supplied to the motor 310 and the amount of the ingredient solution discharged from each of the solution distributors 101 and 201 corresponding to the movement of the supporting block 305 driven by the rotation of the driving motor 310 is previously obtained experimentally, so that the numbers of the pulses per a unit discharge amount of the solution by each of the solution distributors 101 and 201, i.e., P0iL and P0iR (pulses/milliliter) are respectively registered in a first memory 31 in the controller 30 as shown in Table 1.

TABLE 1

SOLUTION NAME	SOLUTION TANK	DISTRIBUTOR IN USE	NUMBER OF PULSES PER UNIT INTAKE SOLUTION AMOUNT
A1L	104-1	101-1	P01L
A1R	204-1	201-1	P01R
A2L	104-2	101-2	P02L
A2R	204-2	201-2	P02R
.	.	.	.
.	.	.	.
.	.	.	.
AiL	104-i	101-i	P0iL
AiR	204-i	201-i	P0iR

The numbers of input pulses PmL and PmR corresponding to the largest strokes of each of the respective pistons 101*b* and 201*b* of the solution distributors 101 and 201, i.e., the largest distance over which the pistons 101*b* and 201*b* can be moved from end-to-end in the cylinders 101*a* and 201*a*, are set and registered in a third memory unit 34 in the controller 30. The sums of the content volume of the intake/discharge pipes from the intake/discharge ports A to the three-way solenoid valves, the remaining content volume of the three-way solenoid valves, the content volume of the ingredient solution pipes between the three-way solenoid valves and the solution tanks and some extra content volume for safety are individually obtained for the solution distributors 101 and 201. In connection with the solution distributor having the largest sum among those obtained, the numbers of pulses PnL and PnR to be fed to the driving motor 310 which correspond to the movement amount of the piston required for discharging the solution of the content volume mentioned above are registered in a fourth memory 35 in the controller 30. The numbers of the pulses PnL and PnR may also be obtained experimentally.

The numbers of pulses PnL and PnR registered in the fourth memory unit 35 are fed to a first comparator unit 37 for comparing the numbers of pulses PnL and PnR with the counted values PiL and PiR fed from an adder 42 to be described later.

When the data of the names of solutions and their respective target injection amounts QiL and QiR are fed to the controller **30**, the numbers of pulses P0iL and P0iR per unit discharge amount of the ingredient solution of the solution distributor connected to the solution tank which contains the solution in question are entered in the first memory unit **31**, and the numbers of pulses PQiL and PQiR corresponding to the target injection amounts QiL and QiR are calculated in a first calculation unit **32** by the following equations:

$$PQiL = P0iL \times QiL, \text{ and } PQiR = P0iR \times QiR$$

In addition, in the first calculation unit **32**, the calculated target numbers of pulses PQiL and PQiR are divided by the produced pulse numbers PmL and PmR respectively corresponding to the largest distances mentioned above for the pistons to be moved, and subsequently, the respective quotients as the numbers of injections nL and nR and their residuals as the numbers of the last injection pulses PqiL and PqiR are registered in the second memory **33** as shown in Table 2. The numbers of injections nL and nR are positive integers 0, 1, 2, . . . and n=0 means the first injection. Accordingly, when the numbers of injections nL and nR are 0, the target pulse numbers PQiL and PQiR become equal to the last injection pulse numbers PqiL and PqiR.

The largest values of the counted numbers of injections nL and nR are registered in an injection number memory unit **43**, and the pistons **101***b* and **201***b* of all the solution distributors **101** and **201** perform reciprocal movements that number of times. In Table 2, it is indicated that each of ingredient solutions A3L and A3R is not injected.

TABLE 2

SOLUTION NAME	SOLUTION TANK	DISTRIBUTOR USED	TARGET PULSE NUMBER	INJECTION TIMES	LAST INJECTION PULSE NUMBER
A1L	104-1	101-1	PQiL	0	PqiL
A1R	204-1	201-1	PQiR	2	PqiR
A2L	104-2	101-2	PQiL	1	PqiL
A2R	204-2	201-2	PQiR	2	PqiR
A3L	104-3	101-3	—	—	—
A3R	204-3	201-3	—	—	—
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
AiL	104-i	101-i	PQiL	nL	PqiL
AiR	204-i	201-i	PQiR	nR	PqiR

Moreover, the solution distributors **101** and **201** are moved approximately the same distance, and the diameters thereof may be different from each other.

By increasing the bore of one or more of the cylinders of the solution distributors **101** and **201**, large amounts of ingredient solutions can be suctioned and discharged by the same amount of movement of the pistons **101***b* and **201***b*, thereby reducing the period of time required for suctioning and discharging the ingredient solutions. On the other hand, by reducing the bores of the cylinders of the solution distributors **101** and **201**, smaller amounts of ingredient solutions can be suctioned and discharged by the same amount of movement of the pistons **101***b* and **201***b*, thereby improving the accuracy of the suctioning or discharging of the solution. That is, since the distance over which the pistons **101***b* and **201***b* are to be moved is fixed, a smaller sectional area of the bores of the cylinders of the solution distributors **101** and **201** enables a rather small amount of solution to be distributed so that a high degree of distribution can be obtained.

Therefore, by selecting a suitable bore for the cylinders of the solution distributors **101** and **201** corresponding to the ingredient solution used and the distribution amount thereof, a desired mixing of solutions can be performed by a smaller number of reciprocal movements of the pistons **101***b* and **201***b*.

Generally speaking, in order to cover a wide range of solution concentrations by plural solution distributors of the same cylinder bore, it is necessary to prepare several concentrations of the ingredient solutions to be suctioned into the solution distributors since the range of the injection amount of the distributors is limited. However, by preparing a plurality of solution distributors having different cylinder bores for ingredient solutions of the same concentration, a wide range in the amounts of solutions discharged can be covered without increasing the number of solution tanks, so that a wide range of solution concentrations can be covered.

Therefore, there is an advantage in that the number of solution mixing operations required for one kind of ingredient solution can be decreased and more kinds of solutions can be used in one automatic solution mixing apparatus.

The automatic solution mixing operation actually performed by each of the solution distributors **101** and **201** will be now described hereinafter for each operating step. In the following description, it is noted that the solution distributors **101** represent all the solution distributors disposed on the left side in FIG. **2**, while the solution distributors **201** represent all the solution distributors disposed on the right side.

[1] SUCTION AT THE SOLUTION DISTRIBUTORS 101; DISCHARGE AT THE SOLUTION DISTRIBUTORS 201

When an operation start-up signal is issued to the controller **30**, the driving motor **310** is operated (to rotate counterclockwise, for example) so as to move the supporting block **305** to the right in FIGS. **2** and **3**. At this time, the three-way solenoid valves **103** are de-energized to open the valve passages COM-NO to the solution tanks **104**. Accordingly, the pistons **101***b* of the solution distributors **101** are moved backward according to the right-hand movement of the supporting block **105**, namely, the common base plate **302**, so that the ingredient solutions in the solution tanks **104** are suctioned and fed into the cylinders **101***a* of the solution distributors **101**.

At this time, the three-way solenoid valves **203** at the side of the solution distributors **201** opposing the solution distributors **101** are de-energized to open the valve passages COM-NO to the solution tanks **204**. Accordingly, the pistons **201***b* of the solution distributors **201** are moved forward according to the right-hand movement of the common base plate **302**, so that the remaining ingredient solutions (air if the solutions are not present) in the cylinders **201***a* are discharged and fed into the solution tanks **204**.

The driving motor **310** is rotated to move the supporting block **305** to the right until the detecting bar **312** fixed to the supporting block **305** comes in contact with the limit switch **311***b*. When the supporting block **305** reaches the limit position on the right-hand side and the limit switch **311***b* is operated by the detecting bar **312**, a right-hand movement completion signal is transmitted from the limit switch **311***b* to a calculation control unit **36** in the controller **30** Then, the calculation control unit **36** interrupts power supply to the driving motor **310** through a driving motor control unit **40** so as to stop the rotation of the motor **310** and set the movement amount count value Pi of the supporting block **305** stored in the adder **42** to zero. The movement amount count value Pi is a value obtained by counting the number of pulses of the pulse signal fed to the driving motor **310** to control the operation thereof. The calculation control unit **36** sends a signal for setting the number of injections to zero to the injection number memory unit **43**.

[2] AIR BUBBLE EJECTION AT THE SOLUTION DISTRIBUTORS 101; SUCTION AT THE SOLUTION DISTRIBUTORS 201

Next, the controller **30** reverses the driving motor **310** (clockwise rotation, for example) through the driving motor control unit **40** so as to move the supporting block **305** to the left. The pulse signal fed to the driving motor **310** is at the same time fed to the adder **42** from the driving motor control unit **40**, and the number of pulses fed to the adder **42** is additively accumulated therein. In this case, since all of the three-way solenoid valves **103** associated with the solution distributors **101** are held de-energized, the valve passages are opened to the solution tanks **104**. At this time, the three-way solenoid valves **203** of the solution distributors **201** opposing the solution distributors **101** are de-energized with the valve passages opened to the solution tanks **204**.

Accordingly, the pistons **201***b* of the solution distributors **201** are backward, in other words, moved extended from the cylinders according to the left-hand movement of the supporting block **305**, so that the ingredient solution in the solution tanks **204** are suctioned into the cylinders **201***a* of the respective solution distributors **201**.

The count value Pi added in the adder **42** in accordance with the operation of the driving motor **310** is successively fed to the first comparator **37** through the calculation control unit **36**, and the first comparator **37** compares the count value Pi with the pulse number PnL fed from the fourth memory unit **35**. When the count value Pi becomes equal to the pulse number PnL, the first comparator **37** sends out the signal for stopping the rotation of the driving motor **310** so as to once stop the rotation of the driving motor **310**. In addition, the calculation control unit **36** sets the added value added in the adder **42** to zero according to the signal supplied from the first comparator **37**.

The purpose of moving the pistons **101***b* of the solution distributors **101** once to the left is to push back all of the air bubbles mingled in the solution distributors **101** to the solution tanks **104** during the solution suction operation so as to ensure that there are no air bubbles present between the intake/discharge ports A of the solution distributors **101** and the three-way solenoid valves **103**. Such an air bubble ejection may be performed during the end-to-end movement of the pistons, and the solutions ejected from the cylinders can be either returned to the solution tanks or disposed of. In this case, the ingredient solutions are again supplied to the cylinders **101***a* of the solution distributors **101**.

[3] INDIVIDUAL DISTRIBUTION AT THE SOLUTION DISTRIBUTORS 101; SUCTION AT THE SOLUTION DISTRIBUTORS 201

In response to the signal transmitted from the calculation control unit **36**, the second comparator unit **39** energizes the three-way solenoid valves **103** associated with one or more solution distributors **101** which are required to discharge the solutions into the receivers **105**, based on the data signals fed to the second memory unit **33** from the first calculation unit **32** so as to open the valve passages COM-NC of the three-way solenoid valves **103** to place the solution distributors **101** in communication with the receivers **105**. Accordingly, when the pistons **101***b* of the solution distributors **101** are moved forward, that is, when retracted into their cylinders **101***a*, the ingredient solutions in the solution distributors are discharged into the receivers **105**.

At this time, the three-way solenoid valves **203** of all of the distributors **201** located on the right, oppositely to the solution distributors **101**, are de-energized and the valve passages COM-NO thereof are opened to the solution tanks **204**. Accordingly, when the pistons **201***b* of the solution distributors **201** are moved backward according to the left-hand movement of the common base plate **302**, the ingredient solutions in the solution tanks **204** are suctioned into the cylinders **201***a* of the solution distributors **201**.

Subsequently, the calculation control unit **36** operates the driving motor **310** through the driving motor control unit **40** so as to move the common base plate **302** to the left. Therefore, the ingredient solutions are discharged from the corresponding solution distributors **101** to the receivers **105**, and at the same time, the pulse signal supplied to the driving motor **310** is fed to the adder **42**, which accumulates the number of pulses and sends the accumulated value to the calculation control unit **36** successively.

The second comparator unit **39** compares the target number of pulses of the solution distributors **101** with the number of pulses supplied from the adder **42**. When the smallest value PQiL of the target number of pulses becomes equal to the number of pulses produced from the adder **42**, the second comparator unit **39** sends a signal for stopping the rotation of the driving motor **310** temporarily to the driving motor control unit **40**. The second comparator unit **39** further de-energizes the three-way solenoid valve **103**-*i* connected to the solution distributor **101**-*i* corresponding to the target number of pulses PQiL through a three-way solenoid valve control unit **38**.

Accordingly, the ingredient solution in the solution distributor **101**-*i* is prevented from being discharged to the receiver **105**-*i*, and thereafter, the ingredient solution in the solution distributor **101**-*i* is discharged to the solution tank **104**-*i*.

In this embodiment, although the valve passages of the three-way solenoid valves **103** are switched over after the driving motor **310** has been temporarily stopped, it is also possible to switch over the valve passages of the three-way solenoid valves **103** without temporarily stopping the rotation of the driving motor 310. In this case, the time required for distributing the solution can be shortened.

On the other hand, at this time, since all the three-way solenoid valves 203 of the solution distributors 201 are de-energized, the valve passages COM-NC thereof are opened to the solution tanks 204, and even when the flow of the discharged solution from the three-way solenoid valve 103-*i* of the solution distributor 101-*i* is changed, the pistons 201*b* are moved backward in accordance with the left-hand movement of the supporting block 305 as mentioned above, and the ingredient solutions in the solution tanks 204 are successively suctioned into the cylinders 201*a* of the solution distributors 201.

Subsequently, the calculation control unit 36 operates the driving motor 310 again to move the common base plate 302 to the left. As in the operation mentioned above, the second comparator unit 39 compares the next smallest value PQiL of the target number of pulses with the number of pulses produced from the adder 42. When the next smallest value PQiL is equal to the number of pulses produced from the adder 42, the rotation of the driving motor 310-is temporarily stopped again and the associated three-way solenoid valve 103-*i'* is de-energized.

On this occasion too, since the three-way solenoid valves 203 associated with the solution distributors 201 are de-energized, their valve passages COM-NO are opened to the solution tanks 204. Therefore, even when the flow of the solution in the three-way-solenoid valve 103-*i'* associated with the solution distributor 101-*i'* is changed, the pistons 201*b* are moved backward in accordance with the left-hand movement of the common base plate 302 as mentioned above, and the ingredient solutions in the solution tanks 204 are successively suctioned into the cylinders 201*a* of the solution distributors 201.

In this way, starting from the solution distributor which has attained the solution mixing operation corresponding to the target number of pulses set in the second memory unit 33, the valve passages of the three-way solenoid valves 103 associated with the corresponding solution distributors are switched over so as to be open to the solution tanks 104 and thereby complete the discharge of the solutions into the receivers 105.

[4] DISCHARGE OF REMAINING SOLUTION IN THE SOLUTION DISTRIBUTORS 101; SUCTION AT THE SOLUTION DISTRIBUTORS 201

The third comparator unit 41 compares the number of pulses supplied from the adder 42 with the number of pulses PmL for the largest piston movement of the solution distributor set in the third memory unit 34, and when the pulse numbers are coincident with each other, the rotation of the driving motor 310 for moving the supporting block 305 to the left is stopped and all the three-way solenoid valves 103 associated with the solution distributors 101 are de-energized and the valve passages thereof are switched over to be opened to the solution tanks 104. The number of pulses PmL indicates the number of pulses which corresponds to the amount of movement of the detection bar 312 necessary to actuate the limit switch 311*a* at the left side for sending the detection signal when the pistons 101*b* are completely inserted into the cylinders 101*a* of the solution distributors 101. Therefore, the limit switch 311*a* nay be omitted by using the number of pulses PmL corresponding to the largest amount of movement of the pistons 101*b*.

At this time, the three-way solenoid valves 203 associated with the solution distributors 201 are de-energized and their valve passages COM-NO are opened to the solution tanks 204. Accordingly, the pistons 201*b* of the solution distributors 201 are moved backward in accordance with the left-hand movement of the common base plate 302, and the ingredient solutions in the solution tanks 204 are continuously suctioned into the cylinders 201*a* of the solution distributors 201 until the left-hand limit switch 311*a* is turned on so as to stop the common base plate 302. When the pistons 201*b* reach the backward limit position and the limit switch 311*a* is actuated by the detection bar and sends out the signal for stopping the rotation of the driving motor 310, the number of injections to be stored in the injection number memory unit 43 is replaced with a value that is one less than the current number of pulses stored in the memory unit 43.

[5] SUCTION IN THE SOLUTION DISTRIBUTORS 101; AIR BUBBLE EJECTION, MEASUREMENT AND RETURN AT THE SOLUTION DISTRIBUTORS 201

Next, in the case where the injection number sent out from the injection number memory unit 43 is not zero, the calculation control unit 36 reverses the rotation of the driving motor 310 and operates the driving motor 310 until the right-hand limit switch 311*b* is turned on. In this case, the supporting block 305 does not move from the left end to the right end but moves as described later. Accordingly, since the common base plate 302 connected to the pistons 101*b* of the solution distributors 101, i.e., the supporting block 305, is moved to the right, the ingredient solutions are suctioned from the solution tanks 104 into all of the solution distributors 101. In addition, by turning on the limit switch 311*b* as mentioned above, the calculation control unit 36 sets to zero the count value Pi for the amount of movement of the supporting block 305 to be stored in the adder 42.

The operation from the time when the left-hand limit switch 311*a* is turned on to the time when the right-hand limit switch 311*b* is turned on will be hereinafter described with regard to the solution distributors 201 located at the right side.

[5-1] SUCTION IN THE SOLUTION DISTRIBUTORS 101; AIR BUBBLE EJECTION IN THE SOLUTION DISTRIBUTORS 201

When the limit switch 311*a* is turned on, the pistons 201*b* of the solution distributors 201 are fully extended to the leftmost position with the three-way solenoid valves 203 opened to the solution tanks 204, so that every cylinder 201 is filled with each ingredient solution.

Then the controller 30 reverses the rotation of the driving motor 310 (counterclockwise rotation, for example) to move the supporting block 305 to the right. The pulse signal fed to the driving motor 310 from the driving motor control unit 40 is at the same time fed to the adder 42 and the number of pulses fed to the adder 42 is additively accumulated in the adder 42.

The count value Pi added in the adder 42 is successively fed to the first comparator unit 37 through the calculation control unit 36. The first comparator unit 37 compares the count value Pi with the number of pulses PnR supplied from the fourth memory unit 35. When the count value Pi becomes equal to the number of pulses PnR, the first comparator unit 37 sends out a signal to the driving motor control unit 40 for stopping the rotation of the driving motor 310. Thus, the rotation of the driving motor **310** is temporarily stopped. In addition, in response to the output signal of the first comparator unit **37**, the calculation control unit **36** sets the added value in the adder **42** to zero.

The purpose of moving the supporting block **305** temporarily to the right is to push out all the air bubbles mingled in the solution in the solution distributors **201** during the solution suction operation to the solution tanks **204** so as to ensure that there are no air bubbles present between the solution distributors **201** and the three-way solenoid valves **203**.

[5-2] SUCTION IN THE SOLUTION DISTRIBUTORS 101; INDIVIDUAL DISTRIBUTION IN THE SOLUTION DISTRIBUTORS 201

Next, in response to the signal transmitted from the calculation control unit **36**, the second comparator unit **39** energizes the three-way solenoid valves **203** associated with the solution distributors **201** required to discharge the solutions into the receivers **205** based on the data supplied to the second memory unit **33** so as to place the solution distributors **201** in communication with the receivers **205**. Accordingly, when the pistons **201***b* of the solution distributors **201** are moved to the right, the solutions in the solution distributors **201** are discharged into the receivers **205**.

Next, the calculation control unit **36** sends a signal to the driving motor control unit **40** for operating the driving motor **310** to move the supporting block **305** to the right again. Therefore, the solutions are discharged from the corresponding solution distributors **201** into the receivers **205**, and at the same time, the pulse signal supplied to the driving motor **310** is fed from the driving motor control unit **40** to the adder **42** which accumulates the number of pulses and sends out the accumulated value to the calculation control unit **36** successively.

The second comparator unit **39** compares the target numbers of pulses of the solution distributors **201** with the number of pulses supplied from the adder **42**. When the smallest value PQiR of the target numbers of pulses becomes equal to the number of pulses produced by the adder **42**, the signal is transmitted from the second comparator unit **39** to the driving motor control unit **40** for temporarily stopping the rotation of the driving motor **310**.

Then, the second comparator unit **39** sends a signal to the three-way solenoid valve control unit **38** for de-energizing the three-way solenoid valve **203**-*i* associated with the solution distributor **201**-*i* and corresponding to the target number of pulses PQiR. By this operation, the solution in the solution distributor **201**-*i* is not discharged into the receiver **205** thereafter, but is discharged into the solution tank **204**-*i*.

Moreover, in this operation, since all the three-way solenoid valves **103** associated with the solution distributors **101** are de-energized, the valve passages COM-NO of the three-way solenoid valves **103** are opened to the solution tanks **104**. Therefore, even when the flow of the solution through the three-way solenoid valve **203**-*i* associated with the solution distributor **201**-*i* is changed, the pistons **101***b* are moved backward, namely, are extended from the cylinders **101***a* in accordance with the right-hand movement of the supporting block **305** as mentioned above, so that the solutions in the solution tanks **104** are suctioned into the cylinders **101***a* of the solution distributors **101**.

Subsequently, the calculation control unit **36** sends a signal to the driving motor control unit **40** again for operating the driving motor, **310** to move the common base plate **302** to the right. As in the manner mentioned above, the second comparator unit **39** compares the next smallest value of the target number of pulses PQiR′ with the number of pulses produce by the adder **42**. When the next smallest value PQiR′ becomes equal to the number of pulses produced by the adder **42**, the rotation of the driving motor **310** is temporarily stopped again and the three-way solenoid valve **203**-*i*′ corresponding to the next smallest target number of pulses PQiR′ is de-energized. By this operation, the solution in the solution distributor **201**-*i*′ is prevented from being discharged into the receivers **205**, and thereafter, the solution is discharged into the solution tank **204**-*i*′.

Also, in this operation, since all of the three-way solenoid valves **103** associated with the solution distributors **101** are de-energized, their valve passages COM-NO are opened to the solution tanks **104**. Therefore, as mentioned above, even when the direction of the flow of the solution through the three-way solenoid valve **203**-*i*′ associated with the solution distributor **201**-*i*′ is changed, the pistons **101***b* are moved backward, namely, are extended from the cylinders **101***a* in accordance with the right-hand movement of the common base plate **302**, so that the solutions in the solution tanks **104** are suctioned into the cylinders **101***a* of the solution distributors **101**.

In this way, the second comparator unit **39** sequentially switches over the valve passages of the three-way solenoid valves **203**, corresponding to the solution distributors **201** opened to the solution tanks **204**, as the target number of pulses set in the second memory unit **33** are attained, thereby completing the discharge of the solutions into the receivers **205**.

[5-3] SUCTION IN THE SOLUTION DISTRIBUTORS 101; REMAINING SOLUTION DISCHARGE AT THE SOLUTION DISTRIBUTORS 201

The third comparator unit **41** compares the number of pulses supplied from the adder **42** with the number of pulses PmR for the largest piston movement of the solution distributor set in the third memory unit **34**, and when the pulse numbers are coincident, the rotation of the driving motor **310** for moving the supporting block **305** to the right is stopped and all of the three-way solenoid valves **203** associated with the solution distributors **201** are de-energized and their valve passages COM-NO are opened to the solution tanks **204**. The number of pulses PmR corresponds to the amount of movement of the detection bar **312** required to actuate the limit switch **311***b* at the right side when the pistons **201***b* are completely retracted into the cylinders **201***a* of the solution distributors **201**. Therefore, the limit switch **311***b* may be omitted by using the number of pulses PmR corresponding to the largest distance of the movement of the pistons **201***b*.

When the limit switch **311***b* sends out the signal for stopping the rotation of the driving motor **310**, the number of injections to be stored in the injection number memory unit **43** is replaced with a value that is one less than the current number of pulses stored in the memory unit **43**.

In this way, when the supporting block **305** is moved to the right in FIG. **2** until the limit switch **311***b* is actuated, the first solution mixing operation is completed.

and at the same time, the solution suction operation for all of the solution distributors **101** is completed.

[6] REPETITION OF THE PROCEDURES [1] TO [5]

The automatic solution mixing operation mentioned above will be started again from this stage. That is, the first comparator unit **37** operates the driving motor **310** to move the supporting block **305** to the left for ejecting air bubbles mingled in the solution in all of the solution distributors **101** until the added count value PiL of the number of pulses of the pulse signal supplied to the driving motor **310** becomes equal to the number of pulses PnL stored in the fourth memory unit **35** during the automatic solution mixing operation with respect to the solution distributors **101**. In this operation, since every three-way solenoid valve **103** associated with the solution distributors **101** is de-energized, the solutions in the solution distributors **101** are discharged into the solution tanks **104**.

Also, in the solution distributors **201**, in the manner as mentioned above, the three-way solenoid valves **203** are de-energized with their valve passages COM-NO opened to the solution tanks **204**. Accordingly, the pistons **201**_b_ of the solution distributors **201** are moved backward in accordance with the left-hand movement of the supporting block **305**, i.e. common base plate **302**, so that the ingredient solutions in the solution tanks **204** are fed into the cylinders **201**_a_.

Similarly to the operation mentioned above, when the air bubble ejection operation carried out with the solution distributors **101** has been completed, the second comparator unit **39** sends a signal to the three-way solenoid valve control unit **38** for switching on the three-way solenoid valves **103** associated with the solution distributors **101** having the number of injections n which is equal to or more than **1**, thereby opening their valve passages COM-NC for discharging the solutions into the receivers **105**. The second comparator unit **39** operates the driving motor **310** to move the supporting block **305** to the left until the number of pulses produced by the adder **42** reaches the smallest number of pulses among the numbers of pulses corresponding to the remaining solution discharge amount.

When the number of pulses produced by the adder **42** reaches the smallest number of pulses mentioned above, the second comparator unit **39** temporarily stops the rotation of the driving motor **310** and switches off the three-way solenoid valves **103** associated with the corresponding solution distributors **101** so that valve passages COM-NO are opened to the solution tanks **104**.

The second comparator unit **39** operates the driving motor **310** again to move the supporting block **305** further to the left. Also in this operation, the three-way solenoid valves **203** associated with the solution distributors **201** are held in the off condition, and their valve passages COM-NO are opened to the solution tanks **204**. Accordingly, the pistons **201**_b_ of the solution distributors **201** are moved backward in accordance with the left-hand movement of the supporting block **305**, so that the ingredient solutions in the solution tanks **204** are suctioned into the cylinders **201**_a_.

In this way, the controller **30** will repeat the operations mentioned above until the solution distributors **101** attain their target discharge amounts. Also, in this operation, the solution distributors **201** will repeat the operations mentioned above corresponding to the solution distributors **101** so as to perform the automatic solution mixing operation.

Thus, in this embodiment of the automatic solution mixing apparatus, by providing a plurality of solution distributors **101** and **201** located on either side of the common base plate **302** on the supporting block **305** which is movable right-to-left with the pistons **101**_b_ and **201**_b_ of the solution distributors **101** and **201** connected to the common base plate **302**, dual solution mixing operations can be performed in the solution distributors **101** and **201** arranged bilaterally. Therefore, even in the case where a plurality of solution distributors are required, it is not necessary to install many assemblies in which the driving gear of pistons and the solution distributors are combined, and therefore, the automatic solution mixing apparatus need not be large. Moreover, since the accuracy in the movement of the pistons of the solution distributors holds for a number of solution distributors, the solution mixing accuracy also is common to the respective ingredient solutions. Accordingly, the accuracy of proportional distribution ratio between the respective ingredient solutions can be improved.

Moreover, since a stepping motor is utilized as the driving motor, the control of the operation thereof can be performed by controlling the number of pulses of the pulse signal supplied to the driving motor **310**, resulting in the elimination of a rotary encoder utilized in a conventional apparatus. Therefore, a cost reduction may be realized together with a simplification of the apparatus because of the elimination of the signal processing system for a rotary encoder, and faults relating to the rotary encoder are obviated. The automatic solution mixing apparatus according to the present invention can attain the same solution mixing accuracy as that in the conventional apparatus without utilizing a rotary encoder.

As described above, according to the present invention, by the provision of pistons of pairs of solution distributors placed face to face each other which move in opposite directions to each other with respect to their respective cylinders by the same amount, while the solution distributors on one side perform the solution distribution, the solution distributors on the other hand can perform solution suction. As a result, a number of solution distribution operations can be performed with a single solution mixing operation without making the automatic solution mixing apparatus large in size. In addition, since the piston movement amounts of the solution distributors on both sides are the same, an identical accuracy for solution distribution may be effected for every distributor.

What is claimed is:

1. An automatic solution mixing apparatus comprising:

at least one pair of solution distributors, each of said distributors including a cylinder and a piston slidably received in said cylinder so as to be reciprocatable relative to said cylinder, and the distributors of each said pair thereof being disposed opposite one another in the apparatus with the pistons thereof extending from their cylinders in opposite directions in the apparatus;

a common base plate interposed between the distributors of each said pair thereof;

a piston coupling mechanism coupling each of said pistons to said common base plate,

said coupling mechanism including a forked member fixed to one of a respective said piston and said common base plate, and a joint member fixed to the other of said respective piston and said common base plate,

said forked member having a pair of arms each having a recessed portion defining a recess therein, and

said joint member being received in the recesses defined in the arms of said forked member and detachably connected to said forked member at the recessed portions of the arms thereof;

a supporting block supporting said common base plate in the apparatus;

a shifting screw operatively connected to said supporting block so as to move said supporting block in the apparatus in respective directions causing the piston of each said solution distributor on one side of said common base plate to extend and the piston of each said solution distributor disposed opposite thereto on the other side of said common base plate to concurrently retract;

first pulley means connected to said shifting screw for transmitting drive to said shifting screw to rotate said screw;

a stepping motor having an output shaft;

second pulley means connected to the output shaft of said stepping motor for transmitting output of the stepping motor; and

transmission belt means extending around said first and said second pulley means for transmitting the output of said stepping motor from said second pulley means to said first pulley means to rotate said shifting screw and move said supporting block.

2. An automatic solution mixing apparatus comprising:

at least one pair of solution distributors, each of said distributors including a cylinder and a piston slidably received in said cylinder so as to be reciprocatable relative to said cylinder, and the distributors of each said pair thereof being disposed opposite one another in the apparatus with the pistons thereof extending from their cylinders in opposite directions in the apparatus;

a plurality of solution tanks provided to supply solutions to said solution distributors;

a plurality of solution receivers provided to receive solution from said solution distributors;

three-way solenoid valves operatively interposed between each of said solution distributors and respective ones of the solution tanks and solution receivers associated therewith, each of said three-way solenoid valves moveable between positions at which valve passages of the valves place the solution distributor associated with the valve in open communication with a said solution tank associated with the distributor and with a said solution receiver associated with the distributor, respectively;

a common base plate interposed between the distributors of each said pair thereof;

a piston coupling mechanism coupling each of said pistons to said common base plate,

said coupling mechanism including a forked member fixed to one of a respective said piston and said common base plate, and a joint member fixed to the other of said respective piston and said common base plate,

said forked member having a pair of arms each having a recessed portion defining a recess therein, and

said joint member being received in the recesses defined in the arms of said forked member and detachably connected to said forked member at the recessed portions of the arms thereof;

a supporting block supporting said common base plate in the apparatus;

a shifting screw operatively connected to said supporting block so as to move said supporting block in the apparatus in respective directions causing the piston of each said solution distributor on one side of said common base plate to extend and the piston of each said solution distributor disposed opposite thereto on the other side of said common base plate to concurrently retract;

first pulley means connected to said shifting screw for transmitting drive to said shifting screw to rotate said screw;

a stepping motor having an output shaft;

second pulley means connected to the output shaft of said stepping motor for transmitting output of the stepping motor;

transmission belt means extending around said first and said second pulley means for transmitting the output of said stepping motor from said second pulley means to said first pulley means to rotate said shifting screw and move said supporting block;

solenoid valve control means for feeding signals to said three-way solenoid valves to selectively move said valves to said positions thereof;

calculation means for calculating data corresponding to a predetermined target quantity of solution to be discharged into said receivers from each of said distributors;

driving motor control means operatively connected to said stepping motor for controlling said stepping motor; and

control unit means operatively connected to said solenoid valve control means, to said calculation means and to said driving motor control means for controlling said solenoid valve control means and said driving motor control means based on the data calculated by said calculation means.

3. An automatic solution mixing apparatus as claimed in claim 2, wherein said calculation means calculates data of a number of pulses by which said stepping motor will operate to cause the predetermined target quantity of solutions to be discharged from each of said solution distributors, by executing the following equations:

$$PQiL = POiL \times QiL,$$

and

$$PQiR = POiR \times QiR$$

wherein PQiL is the number of pulses by which said stepping motor will operate to cause a predetermined quantity of solution to be discharged from a respective one of the solution distributors on one side of said common base plate, PQiR is the number of pulses by which said stepping motor will operate to cause a predetermined quantity of solution to be discharged from a respective one of the solution distributors on the other side of said common base plate, POiL is the number of pulses by which said stepping motor will operate to cause a unit amount of solution to be discharged from the respective one of the solution distributors on said one side of said common base plate, POiR is the number of pulses by which said stepping motor will operate to cause a unit amount of solution to be discharged from the respective one of the solution distributors on said other side of said common base plate. QiL is said predetermined target quantity of solution to be discharged from the respective one of said solution distributors on said one side of said common base plate, and QiR is said predetermined target quantity of solution to be discharged from the respective one of said solution distributors on said other side of said common base plate.

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